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A Brief History of the Forest Insect Division

and its Accomplishments

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Investigations of the biology and control of forest insects have been carried on by Governmental agencies, which now represent the Bureau of Entomology and Plant Quarantine or the Forest Service, almost since the beginning of entomological work in the Department. Dr. Hopkins was called from West Virginia in 1890 to study certain bark beetles by a joint undertaking of the Division of Entomology and Forest Service. This study was greatly extended in 1899, 1900 and 1901, particularly in the Black Hills National Forest. Prior to the establishment of the Bureau of Entomology and some years before the setting up of the Division of Forest Insects, A. S. Packard published his notable contribution "Forest Insects" as the 5th report of the U. S. Entomological Commission. This has been a standard work for many years in forest entomology and is still extremely useful at the present time.

Federal recognition of the importance of forest insects and of the need for organized investigations into the causes of widespread outbreaks, such as that in the Black Hills National Forest, from 1895-1905, was first

conceded in 1902 with a small appropriation of $5,800 to the Bureau of Entomology, United States Department of Agriculture. For the next 2-1/2 decades rapid progress was made in associating the insects with types of damage, in describing the many species which were new to science, in studying their habits and seasonal developments, and in formulating provisional control methods. By 1928 the appropriation for this work had increased to $75,000, and during this period much scientific information was compiled and many ideas originated for the control and prevention of these insect depredations. However, funds were not sufficient to permit adequate experimental testing necessary for the practical application of new control methods. It is obvious that much expense and labor are involved in the experimental testing of methods applied to mature forest trees. Increased appropriations during the period 1928-38, reaching a maximum in 1938 with $253,000, permitted considerable expansion in the thorough testing of the technical knowledge previously gained and its consequent greater application. The improvement and application of this knowledge has resulted literally in the savings of many millions of dollars in control funds and loss of timber and products by land administering agencies such as the Forest Service, National Park Service, Office of Indian Affairs, States and Private Timber Protective Associations and by private operators or home owners. Some of these developments are briefly described in the following pages.

The application of control methods or preventive measures in forest entomology is primarily a problem of management based on a comprehensive knowledge of the insects' biology. Dr. Hopkins early recognized this fundamental principle and expressed it, to quote him, as follows: "The desired control or prevention of loss can often be brought about by the adoption or adjustment of those requisite details in forest management and in lumbering and manufacturing operations, storing, transportation, and utilization of the products which at the least expenditure will cause the necessary reduction of the injurious insects and establish unfavorable conditions for their future multiplication or continuance of destructive work."[1]

The securing of a more exact knowledge of the biology of these insects could be based only on an accurate definition of the species. Working on this thesis, Hopkins encouraged general biological studies, collecting and taxonomic work. He developed a group of specialists including such men as Boving, Burke, Cushman, Fisher, Green, Craighead, Snyder, Kraus, Busck, Heinrich, De Grepe, Rohwer, Middleton, Knull, Champlain, Snodgrass, Fiske, and St. George, who supplemented the small nucleus of taxonomists working under Dr. Howard and later formed the nucleus for the present Division of Identification and Taxonomy. Two of Hopkins' monographs, one on Dendroctonus[2] and one on Pissodes [3] have set a world-wide standard for combined taxonomic and biological considerations in treating groups of insects.

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1 Insects in their relation to the reduction of future supplies of timber, and general principles of control. By A. D. Hopkins, Cir. 129, Bur. Entom. 1910.

2 Hopkins, A. D. (1911) The Genus Dendroctonus, Tech. Ser. No. 17

3 Hopkins, A. D. (1911) Monograph on the Genus Pissodes, Tech. Ser. No. 20

The application of [illegible]

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During the formative period in the study of forest entomology another work of momentous proportions was started by Dr. Hopkins and continued into recent years, which will long rank as an outstanding accomplishment. This is the biological collection of associate notes, adult and immature stages, and samples of work of forest insects. It represents some 3000 genera and possibly ten to fifteen thousand species and now forms the major contribution to the U. S. National Museum collections of the immature stages of Coleoptera, Lepidoptera, Hymenoptera and Diptera and largely makes possible the identification of these stages when intercepted in connection with quarantine enforcement or when received from private individuals or state and federal workers with requests for identification.

Many important publications have resulted from this stimulus.

Toward the latter part of Dr. Hopkins' direction of the Division it became more and more evident, particularly through the work of Miller, Keen, and Craighead, that the answer to many problems in forest entomology could only be obtained by carefully conducted experiments in the laboratory or more often on large sample plots in the forests. This phase of controlled experimental studies has dominated the work of the past 10-15 years under Craighead's direction and takes precedence over all other activities except service work, which is demanding more and more of the time and energy of the Division.

At the present time (1939) the work of the Division is administered through nine large regional laboratories located at Asheville, North Carolina, Berkeley, California, Coeur d'Alene, Idaho, Fort Collins, Colorado, Milwaukee, Wisconsin, Morristown, New Jersey, New Haven, Connecticut, New Orleans, Louisiana, and Portland, Oregon. Experience has shown that the use of a small number of larger laboratories permits the grouping of men, with the resulting stimulus of contact, and also permits locating at large universities or experiment stations where libraries and advisory facilities are available. In addition a scheme of technical cooperation has been developed with the research and administrative men of Forest Service, National Park Service, Forest Pathology of the Bureau of Plant Industry, as well as with several universities, that encourages stimulating contacts and associations.

Bark Beetle Control

Control work against tree-killing bark beetles conducted by three Federal agencies - the Forest Service, the National Park Service, and the Office of Indian Affairs, and by private owners as well, has been an important part of the forest protection program in the western states, and incidentally illustrates marked progress in research and administration.

In the efforts to combat these destructive insects direct measures of artificial control developed by entomologists have, during the past few decades, been applied on a fairly large scale against the more important Dendroctonus beetles, and to a small extent against associated species of bark engravers (Ips spp.) and flatheaded borers (Melanophila).

The first control project of which there is a record was initiated on the Black Hills National Forest in South Dakota in 1906, when $2,700 was expended in an effort to check an epidemic of the Black Hills beetle. Since then many projects have been carried out, some of them covering areas of more than 1,000,000 acres. Up to the present time (Fiscal year 1939) approximately $3,000,000 has been expended in the control of bark beetle infestations, mainly in reserves of timber which are being held until conditions warrant logging and marketing of the lumber.

The annual expenditures from 1906 to 1921 were small - rarely over $20,000 and usually much less. Since 1922, with the fuller appreciation of the importance of the losses brought about through the activities of these insects, increasing amounts have been spent each year for the protection of valuable timber stands. During recent years the Forest Service spent from $100,000 to nearly $200,000 annually, the Park Service from $40,000 to $50,000, and the Office of Indian Affairs from $10,000 to $20,000.

During late years it has been possible to more adequately meet the needs for forest insect control by means of increased funds available to land managing agencies through emergency legislation and CCC labor. During the fiscal year 1937 nearly a million dollars or its equivalent in man-power were utilized in insect control work. Thus, for the first time, the recommendations of the Bureau of Entomology and Plant Quarantine for the protection of our western forests were adequately carried out. Aside from the protection afforded, this work likewise provided large scale tests of several improved methods of control and fully demonstrated their practicability and economy. Hand in hand with this increased activity in control, there developed a demand for greatly expanding our services in surveying infested areas for the purpose of determining the advisability of control and making recommendations as to the most suitable control methods to the land managing agencies handling Federal, State and private timber lands. During the latter

years of this period of expanding control activity, advice on the needs of control was furnished by this Bureau on some 750,000 acres annually and on many of the larger jobs technical assistance was provided as the work progressed. Surveys by this Bureau sometimes exceed 15,000,000 acres annually.

Cooperative Nature of Forest Insect Control: It has already been pointed out that forest insect control involves many technicalities based on an intimate knowledge of the habits of the specific insect causing the damage. It likewise involves the use of a large amount of equipment and requires a detailed knowledge of the topography of the lands under control as well as close contacts with local labor and transportation and market facilities, which are most easily available to the administrative officers on the ground. Due to this combined requirement for technical, entomological, and administrative knowledge, cooperation has been a necessary essential in all past control work.

The responsibility for the investigation of insects affecting forests, or in other words, the discovery of the biological facts on which control rests has been invested by law in the Bureau of Entomology and Plant Quarantine. This law further provides for the cooperation of the Bureau of Entomology and Plant Quarantine with other Federal agencies charged with the protection of Government lands and with private timberland owners.

In 1920 the Secretary of Agriculture drew up a formal cooperative arrangement between the Bureau of Entomology and the Forest Service, clearly defining the respective functions of these Bureaus in research and control. The spirit of this agreement has been carried out with the most harmonious and effective results and has served as a basis for cooperation with the Office of Indian Affairs and the National Park Service of the Department of the Interior. This agreement definitely assigned to the Bureau of Entomology the responsibility for investigations of the insects affecting our forests, and the examination of infested lands, both federal and private, for the purpose of making recommendations as to the cause of the depredations and the necessity for and methods of control. As this has worked out in practice, this Bureau utilizes a considerable portion of its funds for making examinations and conducting surveys of federally and privately owned lands at the request of the agency responsible for the protection of these lands, and also assigns entomologists to aid with technical advice on large control operations. This agreement likewise assigned definite responsibility for the protection of the forests - that is, the carrying out of control operations - to the Forest Service and this principle has been followed ever since in this Department as well as in the Department of the Interior.

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Another form of cooperation is that involving the joint treatment of intermingled or adjacent lands under different ownerships or administrative agencies. Insects are no more restricted by ownership boundaries than is fire, hence the necessity for coordinated suppression efforts. This need is being adequately and harmoniously met by all Federal agencies.

Analysis of Results of Bark Beetle Control Work: Direct control methods were untried to begin with, and their effectiveness could be determined only by actual test in the field. The owner of threatened timber was obliged to make his decision between two courses of action: - either to let nature take its course and await developments, hoping that natural factors would check the insects; or to spend money on expensive direct measures of control, without positive assurance that the results would be profitable or lasting. In spite of the early uncertainty as to what might be accomplished by employing the methods and plans recommended by entomologists, control campaigns of a fairly comprehensive nature have been undertaken on both federal and private timberlands, resulting in a much clearer conception of what can be accomplished and the circumstances under which such large expenditures of money are justified. Unfortunately, because of limited space, it is impossible to present the facts pertaining to each one of these control projects.

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Control methods necessarily must be based upon information regarding the seasonal history and habits of the insects, and also, until thoroughly tried out in practice, upon certain conceptions and theories. In the employment of proposed methods it was at first taken for granted that the killing of beetles saved trees. This theory depended largely on the early assumption that when a newly-developed brood of beetles emerge from an infested tree, they attack and kill another tree in the vicinity, so that each succeeding generation kills a fairly regular quota of trees. Therefore, destroying the broods in one infested tree before they emerge saves at least one living tree from attack by the next generation. This conception, if it were the whole truth, would greatly simplify the problem of estimating costs and appraising benefits derived from control work. Obviously on this basis the volume of timber saved would be in direct proportion to the amount of timber treated. However, it was soon realized that so simple an idea of the problem failed to take into account the complex biotic factors which control the abundance of insect populations and govern the rise and fall of bark beetle epidemics. These even now, after many years' experience in control and investigation, are very little understood.

Other difficulties become obvious when an analysis of the long series of control projects undertaken during the last 35 years is attempted. The following appear to be the most outstanding of these:

(1) Lack of accurate data obtained after the completion of the work from the area treated. Some projects have been closely studied by the Bureau of Entomology, but on many others no attempt was made to measure the actual volume of reinfestation that developed after control work was completed.

(2) Lack of suitable check areas by which a treated area could be compared with an untreated one. To a great extent this lack of checks is due to natural conditions which cannot be remedied. No two areas are ever identical, and seldom even similar in all their aspects, and it is therefore difficult to reach a conclusion on the results of control work by comparison with check areas.

(3) Obscurity of the natural factors influencing the course of the infestation before, during, and after the period of control work. These factors, such as the effects of climatic influences and predators and the distances which beetles fly in reinfesting a control area, may completely outweigh and make it difficult to evaluate the influence of artificial control.

(4) Wide variation in objectives, in the control operations that have been undertaken, and in the values, aesthetic or commercial, to be protected. On recreational areas like those in southern California, control work can be considered successful if only a few trees are saved at high cost. In the commercial

timber stands of the northwest, on the other hand, it is frequently the case that a control operation, to be successful, must cause the permanent saving for the sawmill of a quantity of potential lumber worth more than the amount of money spent in killing the beetles. Therefore, considerations not purely entomological often enter into the appraisal of results on certain projects.

Another phase of the results from control which has received very little consideration up to the present time has to do with the indirect benefits to the forest. These are seldom tangible and are very difficult to estimate. Perhaps the most important is the reduction of fire hazard within the control area through the removal of trees which would otherwise stand as snags to start lightning fires and to spread burning embers when fires occur. Forests which have been swept by bark beetle outbreaks, and in which thousands of dead trees have been left among the surviving live ones, become tremendous fire risks and remain so for many years. Control methods which require the felling of infested trees serve to prevent the accumulation of these dangerous snags in the stand. Projects, therefore, which do not show an actual profit from the viewpoint of the amount of timber saved from beetle attack may in the long run pay through reduction of the fire hazard.

Some forest-protective organizations have maintained yearlong employment for their summer fire-protection force by carrying on insect-control work during the winter period, and consider this good practice, even though the reduction of infestation is not outstanding.

From the considerations just enumerated it is obvious that the entire problem involved in the formulation of a control policy is very complicated and cannot be settled by merely laying down a few hard-and-fast rules as to when and where and under what conditions control work is to be recommended. Local conditions and values, and quite often other considerations that are not entomological, must laregly determine the plans and strategy for each specific project; and these factors should be taken into account in determining the success or failure of each undertaking.

With all these considerations in mind, it is obvious that any broad conclusions as to the results of past projects are subject to many reservations. However, at least one outstanding conclusion applies to the entire matter, and may be stated as follows: Each species of bark beetle presents its own special problem and must be dealt with differently from other species as to control methods and strategy, and even the same species may present problems which differ in different regions. The management of control operations must therefore vary according to local conditions within the area to be protected.

Some of the conclusions on the more important beetles which are held by most forest entomologists at the present time and which serve as rules for guidance in decisions of the Bureau of Entomology and Plant Quarantine and our co-operators, the timberland owners, are as follows:

The Western Pine Beetle: Admittedly the success of the numerous projects for western pine beetle control has not been spectacular or outstanding. In many cases the work has shown tangible results, but often these results were not substantial enough to show a profit. Some projects were apparently failures. The data to prove positively either success or failure of certain projects is often inadequate. Indirect benefits of control work, such as the reduction of fire hazard, are usually too intangible to be appraised. With the data at hand any broad conclusions, therefore, must be based upon convictions of entomologists and owners who have had long experience in this work, rather than upon any overwhelming weight of evidence. The predilection of the western pine beetle for slow-growing trees and its apparently quick response to climatic influences must also be taken into consideration. With these limitations in mind it is the present opinion that direct control of these beetles is justified only under special circumstances. (Ref. - "Control work against bark beetles in western forests" by Craighead, Miller, Keen, Evenden. Jour. For. 1931 Nov.)

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The Mountain Pine Beetle: The adoption of any control policy for the mountain pine beetle in lodgepole pine must be on the premise that an ounce of prevention is worth a pound of cure. To prevent epidemics adequate attention must be given to increasing infestations. A few grouped, insect-infested, trees should be regarded as much a potential danger as a smouldering fire. It is true that the adoption of such a policy of control will result in a much higher cost per tree for treatment than if control work is delayed until epidemic conditions exist. Nevertheless, if proper weight be given to considerations such as the present and expectation values of timber saved through the prevention of epidemics, the potential threat from active epidemics to stands of continuous type even 100 miles distant, the prevention of fires which result in even greater timber losses, and the complete alteration of forest types, which often revert to less valuable mixtures, it will be found that the prompt treatment of developing infestations is the most economical policy to follow.

Until results are obtainable from several large projects now under way on the Coeur d'Alene and Kootenai National forests, it is felt that final conclusions on the effectiveness of artificial control against the mountain pine beetle in the white pine type must be postponed. It appears, however, that much the same results have been obtained here as with lodgepole pine - results that are directly proportional to the percentage of the infestation treated.

The policy to be recommended, therefore, is substantially that suggested for the lodgepole type. Less emphasis, however, need be put on certain features. Associated with the broken distribution of the host and the less active type of infestation there appears to be a relatively less marked tendency for long flight by the adult beetles, indicating that suppression measures of a more local character can be justified.

The Black Hills Beetle: If the extreme aggressiveness of this species, its potentialities for rapid increase under favorable conditions, and the fact that when epidemic it attacks the most vigorous stands, are considered in connection with the results of several properly timed and well executed control projects, it seems only logical to draw the tentative conclusion that prompt, thorough, and persistent control will effectively check outbreaks.

Outstanding Improvements in Control

Control of bark beetles is admittedly expensive, involving as it does, the spotting of infested trees in the forest, followed by felling, barking, and often burning of the bark to destroy the beetles and thus prevent new broods from emerging from infested trees and attacking nearby green trees. Usually the largest trees in the forest are attacked and the labor required for spotting, felling, barking, and burning costs from $2 to $20 per tree, depending on its size, accessibility, type of timber and other factors. Such costs are a limiting factor in the application of control, as frequently the expenditures run too high to make control economically feasible. Of recent years several new methods have greatly reduced these costs.

The so-called "sun-curing method" was tested out on a large scale in lodgepole areas in Oregon by Patterson (1930)[1] and found to be successful under certain conditions. The principle was first applied by Craighead (1920)[2] in 1917 at East Falls Church, Va., on wood boring larvae and a year or so later experiments with Dendroctonus infested logs were conducted by Miller (1921)[3] in California. It consists of simply felling the tree and exposing the trunk to full sunlight, later turning the log to expose the underside. In California the thick bark of yellow pine and sugar pine is first peeled and then spread out in the sun. The heat generated under the bark by the direct rays of the sun is sufficient to kill the brood. Costs in the lodgepole types have been reduced from $1.75 or $2 to 40¢ or 50¢, where this method is applicable.

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1 Patterson, J. E. - Control of the Mt. Pine Beetle by Solar Heat - Tech. Bulletin #195, 1930.

2 Craighead, F.C. - Direct Sunlight as a Factor in Insect Control - Ent. Soc. Wash. May, 1920.

3 Miller, J. M. - Insect Control Policy of Sierra N. F. - Timberman, Apr. 1921.

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About 1926 a method was devised for burning the bark from the lodgepole pine infested trees while standing. This idea originated with W. W. White of the U. S. Forest Service (Arriviee, 1930)[1] and was developed through suggestions from the entomologists Evenden and Gibson. This effectively killed the beetles and cost in the neighborhood of $1.00 per tree when it was possible to get fuel oil into the forest by road. The former type of control cost in the same locality averaged $1.50 - $2 per tree.

The possibilities of injecting chemicals into the sap stream of the tree and thus preventing the development of the bark beetle broods and doing away with the costly operations of felling and barking or burning the tree for the control of bark beetles has been experimentally tested for the past few years. There appears to be much promise in this field both from control and salvage standpoints but it is yet too early to be confident of results. (See other discussion)

One of the disadvantages of bark beetle control has been the loss of the lumber from the tree which is treated. Usually the cost of control is greater than the actual lumber value of that particular tree and benefits of the control work must come through the saving of timber values in other unattacked trees on nearby

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1. Arriviee, David, An adventure in bug hunting - American Forests and For. Life - February 1930

areas through prevention of the spread of the infestation. For this reason a great deal of attention has been devoted by our entomologists in the last few years to the use of so-called salvage methods of control and the Forest Service and private timberland owners have cooperated heartily. In the ponderosa pine types of eastern Oregon and northeastern California when the terrain permits caterpillar logging, prompt spotting and salvage of these trees is feasible.[1] In other types particularly in the Rocky Mountain regions, a number of incipient outbreaks have been controlled through local use of the infested tree before the outbreaks developed into serious proportions.

It has long been desirable to have a method of treating infested trees through the summer period, and one that would be quick in action and avoid the use of fire which is so dangerous at that time of year. After considerable experimentation, begun in 1931) by Miller and Hensil (1938)[2] in California through the cooperation of Norman Gay of the Standard Oil Company of California, several penetrating chemical sprays were finally developed which very effectively met this need. The most promising chemicals are orthodichlorobenzene and naphthalene dissolved in light mineral fuel oil. This method is particularly well suited to the control

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1. Keen, F. P. - Pine Beetle Control Costs Reduced through Logging and Salvage. USDA Yearbook 1931 pp. 428-430

2 Salman, K. A. - Recent experiments with penetrating oil sprays for control of bark beetles, Journ. Econ. Ent. March, 1938.

of mountain pine beetle broods under the thin bark of lodgepole pine in the Northern Rocky Mountain region.

During the past year the application of these same sprays has been tested by Collins and Whitten on elm logs infested with Scolytids, in connection with control of the spread of the Dutch elm disease fungus. Preliminary results are so satisfactory that it is likely the methods will have great practical importance in treating wood piles and other logs which previously have been difficult to handle from an administrative standpoint.

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The Prevention of Forest Insect Losses by Forest Management

Forest entomology is not only a science of protection but one of prevention as well. It is obviously better to prevent outbreaks of insects from becoming destructive than to wait until they have gained such momentum as to make direct control necessary. This objective will be attained more fully in the future through proper silvicultural practices applied to the growing stands whereby unfavorable conditions for the development of the insects are maintained or greater resistance of the stand to insect attack is developed. To determine the necessary practices for this form of protection close cooperation between the personnel engaged in other phases of forest research and entomologists of the Bureau of Entomology and Plant Quarantine has been developed at the Forest Service Experiment Stations. Some of the more practical results are mentioned below.

For a number of years prior to the conclusion of recent studies the bronze birch borer was regarded by some entomologists and foresters as a serious problem in the management of mixed hardwood stands in northern New England and the Lake States. It is of practically no importance in an uncut forest, except in one which is growing on a very poor site or which is overmature and where general decadence has set in, but appears in great numbers coincident with the death of the trees left after partial cutting

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of the original stand. It has been shown that the changes in the physical factors of the environment brought about through the medium of logging are often such that birch trees left on the area will succumb without the attack of either insects or fungi, and that the borer plays only the role of a secondary factor in hastening post-logging decadence.[1 - 2]

The application of these studies has indicated that selective logging in any forest which contains a large percentage of birch is a dangerous practice where more than 25% of the basal area of a stand is removed. Where cutting is heavier than this, factors of decadence, of which the bronze birch borer constitutes only a minor one, are such that losses will more than offset growth in the period following cutting.

Through the combined efforts of entomologists and foresters, simple silvicultural practices have been devised for the correction of white pine weevil damage in the New England region. MacAloney, 1932[3], Cline and MacAloney, 1933[4].

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1. Spaulding and MacAloney - Decadence of Birch on Cut Over Lands - Jour. For. Dec. 1931.

2. Hall, R. C. - Post Logging Decadence in Northern Hardwoods, Univ. of Mich., School of Conservation, Bull. No. 3 - 1933.

3. MacAloney, H. J., The White Pine Weevil, USDA Cir. #221 - 1932.

4. Cline and MacAloney - A Method of Reclaiming Severely Weeviled White Pine Plantations - Mass. For. Assoc. 1931.

By restricting plantings of pure white pine to better sites and by the group-wise development of pine and hardwoods on sites that permit, serious weevil damage can be effectively prevented. Also by judicious pruning of crop trees and girdling of wolf trees, stands already badly damaged can be made to produce a reasonably profitable crop. These results have greatly changed the pessimistic picture of a few years ago for the growing of this valuable tree.

Early studies of the gypsy moth, ever present pest of hardwood forests in the New England states, developed the fact that the presence of certain species of trees was necessary to maintain infestations while in the absence of these favored food plants, the insects could not develop. Mosher, 1915[1], Clement, 1917[2]. By means of experimental plots in cooperation with the Harvard Forest School and the Northeastern Forest Experiment Station, means of adapting this knowledge to silvicultural practices have been developed, which should make it possible to grow forests free from serious injury by the Gypsy moth. Baker, 1935[3], 1936[4].

The production of spruce and fir pulpwood in the New England region is intimately associated with the activities of the spruce budworm. Recent investigations have shown that the mortality in various stands following attack of this insect is directly correlated with the vigor and the composition of the stand. In other words, if rapid growth and a low percentage of fir is maintained, the forest will be practically immune.[5]

1. Mosher, F.H., Food plants of the gypsy moth in America, USDA Bull. 250, July 1915
2. Clement, G. E. and Willis Munro, Control of the gypsy moth by forest management. USDA Bull. 484, 1917.
3. Behre, Cline, Baker - Silvicultural control of the gypsy moth - Mass. For. & Park Assoc. - Aug. 1936
4. Baker, W.L. & Cline, A.C., A study of the gypsymoth in the town of Petersham in 1935 - Journ. For., Vol. 34 No. 38.
5. Craighead, F. C. - Budworm and Growth - J.A.R., Mar. 1925

The woods practices of a decade ago in the naval-stores industry in the South resulted in extravagant losses from dry facing and windthrow. The latter frequently affected such a high percentage of the stand that the crop was abandoned. This windthrow was in a large measure the result of the weakening of the trees by an insect boring in the heartwood of the tree. It gained entrance to the tree through the faces in the turpentined timber. Investigation showed that this loss was preventable through the adoption of conservative turpentining practices which at the same time increased the yield of gum and greatly prolonged the period of operation on a given area.[1,2]

The locust borer now widely distributed throughout most of the U.S. is a serious menace in many localities to the growing of this valuable tree. Early studies, Craighead[3], indicated that damage was proportional to the density or amount of shading of the stand, and that close planting and mixed stands were desirable. Later Hall[4] presented the conclusion that rapidity of growth instead of shade was the important factor and emphasizes planting only on good sites.

1.Craighead, F. C. - The Turpentine Borer, For. Worker, 1927
2.Beal, J. A. Control of Turpentine Borer, USDA Cir. 226, 1932
3.Craighead, F. C. Protection from the Locust Borer, USDA Bull 787.
4.Hall, R. C. - The relation between locust borer damage and site. Journ. For. Vol. XXX No. 3 Mar. 1932 pp. 341-342.

Detailed studies of the habits of the western pine beetle have greatly increased our knowledge as to the ecological and silvicultural relationships of this important bark beetle enemy of ponderosa pine in northeastern California and eastern Oregon forests. It has been found that beetle epidemics are usually associated with drought conditions or poor tree growth, while the natural control of epidemics frequently follows increased precipitation and improved growth conditions. Also a marked selectivity of the beetle for pines of certain characteristics has been pointed out by Craighead, 1925[1], Dunning, 1928[2] and Person, 1928[3]. Keen, 1936[4], expanding these studies, developed a tree classification based primarily on tree age and vigor and determined the broad tree classes showing greatest susceptibility to bark beetle attack. This tree classification incidentally has been adopted by foresters as a basis for silvicultural studies and marking rules in ponderosa pine forests of the Pacific Northwest and has stimulated development of similar tree classifications for other regions and other tree species. More recently K. A. Salman (unpublished reports) has carried the application of this selectivity of the bark beetles for certain trees to the making of a hazard rating of the trees for use in salvaging high-risk trees through immediate sale and cutting. Thus, the selectivity which this bark beetle exhibits for trees of certain characteristics will have an important bearing upon forest management practices in this timber

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1. Craighead, F. C. - The Dendroctonus Problems, Jour. of For. Vol. XXII, 1925.
2. Dunning, Duncan - A Tree classification for the selection Forests of the Sierra, Nevada. Jour. Agr. Res. 36:755-771, illus.
3. Person, H. L. - Tree selection by the western pine beetle. Jour. For. 26:564-578.
4. Keen, F. P. - Relative Susceptibility of Ponderosa pines to bark beetle attack - Jour. of For., Oct. 1936, Vol. 34 #10.

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type and in revising marking rules. It is hoped that it will make feasible the removal by cutting of susceptible trees before they are attacked by bark beetles and thus will greatly reduce or lessen the tremendous losses suffered annually from the activities of these beetles.

Miscellaneous Developments

Tree Rings, Insects and Climate: That the annual rings of a tree are a record of its past and present state of health and something of an expression of the vicissitude of its past life has been well proven in recent years. Contributions to this knowledge and its application to practical problems have been made by workers in this Division. Craighead, 1924[1], pointed out the effect of spruce budworm defoliation on the growth rings of spruce and fir and showed how such evidence could be used for the dating of defoliation outbreaks. Later, defoliation by fire, Craighead, 1927[2], was shown to produce a similar effect which could be used to accurately date fire. Keen, 1937[3], has given ample confirmation of a distinct correlation between bark beetle infestations and climatic trends, as indicated by the growth of trees. He has shown that

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1. Craighead, F. C. - Studies on the spruce budworm - Part II - Bull. 37, Dom. of Canada, Dept. of Agric. 1924.
2. Craighead, F. C. Abnormalities in annual rings resulting from fires - Journ. of For. - Nov. 1927.
3. Keen, F. P., Climatic cycles in eastern Oregon as indicated by tree rings - Monthly Weather Review, 1937.

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the tremendous severity of bark beetle outbreaks for the past 15 years is undoubtedly correlated with a period of insufficient moisture and slow growth. Similar periods have occurred at several times during the past 600 years but none so severe as the current one. We are hoping that we are coming out of this cycle. This study, has, however, a wide application outside the field of entomology. The relation of drought to the hickory bark beetle outbreaks was first reported by Felt and later confirmed by Blackman, 1924,[1] Craighead, 1925,[2] showed the application to outbreaks of the Southern pine beetle and Jaenicke (?) to the western pine beetle, and Blackman, 1932[3] and Beal, 1939, to the Black Hills beetle.

<u>The Effect of Low Temperatures on Bark Beetles</u>: A number of observations have been made by the workers of this Division and by foresters on the effectiveness of low temperatures in controlling bark beetle outbreaks. Hopkins, 1899,[4] cites the cessation of a *Dendroctonus frontalis* outbreak in West Virginia in 1892. Later Beal, 1927,[5] worked out the effect of cold on this species more accurately. Miller, 1931[6], first reported similar lethal effects of high and low temperatures for the western pine beetle *Dendroctonus*

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1. Blackman, M. W. - The effect of deficiency and excess of rainfall upon the hickory bark beetle - Jour. Ec. Ento. 1924.
2. Craighead, F. C. - Bark beetle epidemics and rainfall deficiency.- Journ. of Economic Ent., Vol. 18, #4, p.577-586. 1925.
3. Blackman,M.W. - The Black Hills Beetle -N.Y.S.College of For. - Tech. Pub. 36, 1932.
4. Hopkins, A.D.-Report on Dying Spruce and Pine in West Virginia - W. Va. Agr. Exp. Sta. Bull. 56 - 1899.
5. Beal,J.A. - Weather as a Factor in Southern pine beetle control - Jour. For. October, 1927.
6. Miller,J.M. - High and Low Lethal Temperatures for the Western Pine Beetle. J.A.R. Aug. 1931.

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brevicomis, in 1931 and later, 1933,[1] showed how important low temperatures could be in effecting natural control and thus saving direct control expense. Later, Keen and Furniss, 1937,[2] mad a detailed analysis of the effect of two critical winters of subzero temperatures on populations of the western pine beetle.

We are now systematically checking on the effects of low temperatures on several species of *Dendroctonus* in field and controlled laboratory experiments at all our western laboratories.

It has been found that during the coldest winter months most of the larvae of the mountain pine beetle will survive at temperatures down to -35 and -40° F. in the northern Rocky Mountain region; whereas in the warmer climate near the Pacific Coast, they are killed at -10° which is also the critical temperature for overwintering larvae of the western pine beetle. During the spring and fall the insects are much less resistant to cold and are killed at much higher temperatures. When these experiments are completed, it will be possible to predict the extent of beetle mortality in nature, where extremely low or unseasonal temperatures occur. This will have a direct bearing on large control projects, making it possible to recommend immediate cessation of the control work whenever sufficiently low temperatures occur to control the beetles naturally. Already

1. Miller, J. M.--A record of winter kill of western pine beetle in California, 1932. - Jour. of Forestry 31 (4): 443-6, Apr. 1933.
2. Keen, F. P., and Furniss, R.L.--Effects of subzero temperatures on populations of the western pine beetle.--Jour. Econ. Ent. 30 (3), pp. 482-504, June 1937.

with incomplete data that we now have, several large projects have been stopped and a total saving made of far more than the total cost of the work to date at our four western laboratories.

Insects and Disease: For many years entomologists have recognized the close association of insects and diseases in the forest and many citations have been made to this general association. However, of recent years cooperation between the specialists has brought to light a much more close relationship, even a symbiosis in certain cases.

One of the most important of these intimate relationships is that between so-called blue stains and Dendroctonus. The significance of this relationship was first pointed out by Craighead, 1925[1], and developed by Beal and Nelson, 1929[2]. These fungi are introduced by the beetles and play an important role in hastening the death of the tree and making conditions favorable for the development of the bark beetle broods. Later Struble, 1937[3], demonstrated this same relationship for a Scolytus species in dying fir, and Wright, 1938, for other species of Scolytus in fir. These discoveries were instrumental in stimulating a great deal of work in this field in this country and in Europe, Leach, Orr and Christensen, 1934[4], 1937[5]

1. Craighead, F. C. - The Dendroctonus Problems - Jour. For. Apr. 1925.
2. Beal, J. A. and Nelson, R.M. - Experiments with Bluestains - Phytopathology - Vol. 19 - #12, 1929.
3. Struble, G. R. - The Fir Engraver Beetle, A Serious Enemy of White and Red Fir. - USDA Cir. 419, Jan. 1937.
4. Leach, J. G., Orr, L. W. and Christensen, Clyde - The Interrelationships of bark beetles and blue-staining fungi in felled Norway pine timber - Jour. of Agric. Res. Vol. 49 #4, 1934.
5. Leach, J. G., Orr, L. W., and Christensen, Clyde - Further studies on the interrelationship of insects and fungi in the deterioriation of felled Norway pine logs - Jour. Agric. Res., Vol. 55 #2, 1937.

Later the Dutch elm disease was introduced from Europe and such relationships were proven to exist between this fungus and Scolytus by European workers. It has subsequently been confirmed and extended by entomologists of this Division at our Morristown, N. J. laboratory.[1,2]

An insect-fungus relationship for the disease causing the so-called Prescott Twig Blight was suspicioned and an investigation revealed that some species of Matsucoccus were primarily responsible for this type of injury, even without the presence of a fungus, McKenzie . Work by Parr (1939 - not yet published) following earlier studies of the golden oak scale demonstrated that these Matsucoccus species can kill twigs by injection of enzymes into the growing tissue.

The relationship of insects to the Chestnut blight was reported by Craighead, 1916,[3] as being that of making wounds for the entrance of spores and of feeding on and destroying the sporophores.

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1. Middleton, Wm., Buchanan, W. D., May, Curtis, and Walter, J.M. - Ceratostomella (Graphium) ulmi, the cause of the Dutch elm disease, transmitted by Scolytus multistriatus. - Jour. Econ. Ent. 28:138. 1935.
2. Collins, C. W., Buchanan, W. D., Whitten, R.R., and Hoffmann, C. H. - Bark beetles and other possible insect vectors of the Dutch elm disease Ceratostomella ulmi (Schwarz) Buisman. - Jour. Econ. Ent. 29 (1):169-176. 1936.
3. Craighead, F. C. - Insects in Relation to Chestnut Blight - Science, 1916 January.

<u>The Sap Stream Method of Treatment of Living Trees and Forest Products</u>: Prompted by the reported results of treating diseases of fruit trees by the introduction of chemical salts into the sapstream, Craighead (1926) made some preliminary trials at the Asheville laboratory to test the possibilities of this method for treating pines infested with the Southern pine beetle and for treating green wood to prevent insect attack and decay. Preliminary results were encouraging and the next few years Beal and St. George devoted considerable time to this problem. The previously described technique was not satisfactory for our purposes and by 1928 it was determined that the chemical must be introduced completely around the circumference of the stem to insure proper penetration and distribution to all parts. Additional work was conducted at our Asheville[1], Coeur d' Alene[2] and Morristown[3] laboratories and important developments in perfection of technique of application have been devised by Evenden, Rust, Wilford[4] Collins, Whitten and Lantz.

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1. Craighead, F. C., St. George, R. A. - Experimental work with the introduction of Chemicals into the sapstream of trees for the control of insects - Jour. of For. - Jan. 1938, Vol. XXXVI, No. 1.
2. Bedard, W. D. - Control of the Mountain pine beetle by means of chemicals - Jour. For. January 1938.
3. Brief E-434 - An efficient method for introducing liquid chemicals into living trees - May 1938.
4. Brief E-409, Craighead, F. C., St. George, R. A. and Wilford, B. H., A method for preventing insect injury to material used for posts, poles, and rustic construction. June, 1937.

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The most practical present result of this experimental work seems to be in its application for the prevention of insect attack and decay to crude forest products, such as poles, posts, and timbers in contact with the ground and material to be used as rustic work, such as furniture, cabins, etc. Thus, it enables the farmers, particularly in the South, to utilize pines and non-durable woods with enormous benefit. It will not compete in any sense with the commercial treatment of cross-ties or poles with creosote.

Modifications of this treatment have been applied to the eradication of the Dutch elm disease (reference later), making it possible to more than cut in half the costs of clear-cutting certain elm areas. The trees treated by this method will not sprout and are not subsequently attacked by insects, thus doing away with the necessity of costly and difficult stump treatment and the barking or utilization of the elm wood to prevent the bark beetle vectors from breeding in it.

It is predicted that future experimentation will make possible the application of this method to the control of shade tree insects through the development of suitable chemicals with a sufficiently high differential in their toxicity toward the plant and the insect, that when introduced into the sapstream they will kill the insects and do no harm to the tree.

Experiments with High Fatal Temperatures: Craighead, in 1921, determined the high critical kiln temperatures for borers in ash logs.[1]

Lyctus powder-post beetle tests conducted by Snyder in 1923 revealed the critical kiln temperatures effective against this insect in infested lumber where dry heat was used.[2] Later in 1924, St. George and Snyder determined temperatures critical to Lyctus beetles where a saturated atmosphere was used in the kiln.[3] Because of its practical application, this work received considerable attention in England and after verifying these results, further investigations were made abroad to determine the critical temperatures with variations of such factors as thickness of lumber, kiln temperatures and humidity. Recent studies by Snyder indicate that lumber having a moisture content above 15% will be free from Lyctus attack. This fact is of considerable importance to the export lumber trade.

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1. Craighead, F. C. and Loughborough, W. K. - Temperatures fatal to larvae of the red-headed ash borer as applicable to kiln-drying. - Journ. of Forestry - 19:250-254, 1921.
2. Snyder, T. E. - High Temperatures for the control of Lyctus powder-post beetles. - Journ. Forestry 21: 810-814, 1923.
3. Snyder, T. E. and St. George, R. A. - Determination of Temperatures fatal to the powder-post beetles, Lyctus planicollis, by steaming infested ash and oak lumber in a kiln. - Journ. Agr. Research 28:1033-1038, illus. 1924.

Lyctus Experiments: - The powderpost beetles have been the subject of serious study from the early days of the Division. The manner of oviposition of Lyctus in the pores of the wood was first demonstrated by Xambeu[1] in 1898, while studying the European form Lyctus linearis Goeze (Canaliculatus Fab.), and later confirmed by Snyder[2] in 1916 when studying the Southern Lyctus, L. planicollis Lec. The discovery of this habit furnished the basis for later recommendations for the prevention of damage through filling the wood pores with oil, wax, or paint. The inability of Lyctus to develop in wood which had been held in water several months was first noticed by Craighead on oak at Vicksburg, Miss. (1918) and checked the next few years by St. George at Falls Church and first mentioned in the annual report of the Chief for 1922. Although this was independently determined here, it was previously reported in France.

Dr. Hopkins throughout the entire period of his investigations of forest insects had been intensely interested in the phenomena of difference in timing of plant and insects events from the southern part of the country to the north with the advent of spring. These studies had considerable practical application in planning investigations and control work in various parts of the country. These observations were published in 1918[3] in a preliminary paper, followed in 1938[4] by his final observations and conclusions.

1. Xambeu, V. - 1898. Moeurs et metamorphoses du Lyctus canaliculatus Fabricius. In. Bul.Soc.Sci.Nat. l'Ouest France, VIII, pp.69-72
2. Snyder, T.E. - 1916 Egg and manner of oviposition of Lyctus planicollis. Jour.Agri.Res.Vol.VI, #7, Dept.Agric.Wash.D.C. pp.273-276, illus.
3. Hopkins, A.D. - Periodic Events and Natural Law as Guides to Agr.Research and Practice - Monthly Weather Review USDA, Suppl. 9, Jan. 1918
4. Hopkins, A.D. - Bioclimatics, USDA, Misc. Pub. #280, Jan. 1938.

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For many years Dr. Hopkins[1] had advocated the application of his so-called "Host Selection Principle" to practical control operations. This, in brief, is stated by him as "species which breed in two or more host plants will prefer to continue to breed in the host to which it has become adapted". Experimental tests of this theory were reported on by Craighead[2,3] in 1921 and 1923. Of late years this principle is not wholly depended on in the protection of valuable timber species when adjacent infestation occurs in another favored host.

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1. Hopkins, A. D. - Economic investigations of the Scolytid bark and timber beetles of North America - USDA Program of Work, 1917, p. 353. 1916.

2. Craighead, F. C. - Hopkins host selection principle as related to certain Cerambycid beetles. - J.A.R. Vol. 22, No. 4, Oct. 1921.

3. Craighead, F. C. The host selection principle as advanced by Walsh. - Canadian Ento. Apr. 1923.

Biological Control: An important phase of the work of this Division has been the utilization of natural insect enemies in attempting to bring about some measure of control of certain forest insects which were accidentally introduced into North America. This work has been centered for the most part in New England where many forest insects of foreign origin occur.

In 1889 a Coccinellid beetle Rodolia cardinalis Muls. was introduced into California to combat the cottony cushion scale, Icerya purchasi Mask. The remarkable success attending this experiment in biological control stimulated this type of work, and an intensive program of parasite introduction against the gypsy and brown-tail moths was undertaken in cooperation with the State of Massachusetts in 1905. In 1911 a report on this work was published by Howard and Fiske.[1]

This report has been a standard reference for workers in biological control, both from the standpoint of methods used as well as for the biologies of the parasites and predators worked with. Many important publications regarding the biologies of specific parasites also appeared as a result of these investigations.

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1. Howard, L. O., and Fiske, W. F. - 1911. The importation into the U. S. of the parasites of the Gypsy Moth and Brown-tail Moth. U. S. D. A., Bur. Ent. Bull. 91, 334 pp. illus.

In 1911 the Bureau of Entomology took over this work in its entirety and, except for an interruption caused by the World War, the work continued until 1932. In 1929 Burgess and Crossman[1] gave an account of the work up to that time. Although importation of gypsy and brown-tail moth parasites was discontinued in 1932, parasites of a number of other forest insects were imported into New England from 1929 through 1937. See Table 1.

During all these years a considerable amount of apparatus has been developed for handling parasites and predators to the best advantage. Burgess and Crossman's account is not only an excellent record of accomplishment, but it gives in detail methods used in collecting, shipping, breeding and colonizing parasites. Many of these methods are illustrated in their bulletin, and most of them or modifications of them have been used extensively by other organizations engaged in parasite work. In addition to these, many other methods have been developed in connection with handling other host species. Collins and Holbrook[2] devised an excellent trap for collecting predaceous arboreal predators.

1. Burgess, A. F., and Crossman, S. S. - Imported insect enemies of the gypsy moth and the brown-tail moth. U.S.D.A. Tech. Bull. No. 86, 147 pp. illus.

2. Collins, C. W. and Holbrook, J.E.R. - Trapping Calosoma beetles. Journ. Econ. Ent. Vol. 22, No. 3, June 1929.

1.
Sellers, W. F. - A parasite rearing tray developed to meet special requirements. ET 74 - Feb. 1936.

2.
Dowden, Philip B. - 1934. Recently introduced parasites of three important forest insects. Annals Ent. Soc. America, Vol. 27, No. 4, pp. 599-603

3.
Jones, T. H., Dowden, P. B. and Webber, R. T. 1938 Effectiveness of Imported Insect Enemies of the Satin Moth. USDA Cir. 459. 24 pp. illus.

4.
Glaser, R. W. Wilt of gypsy moth caterpillars. Journ. Agr. Res. Vol. IV, No. 2 - 1915

Glaser, R. W. A new bacterial disease of gypsy-moth caterpillars. Journ. Agr. Res. Vol. XIII, No. 10 - 1918.

Speare, A. T. and Colley, R. H. The artificial use of the Brown-Tail fungus in Massachusetts. State Forester's Publication. 1912.

Sellers[1] developed special trays for rearing parasites of the European pine shoot moth. He also devised a special cage for hibernating Tachinid puparia (Unpublished). Dowden[2] briefly describes methods for shipping foreign parasites.

In addition to the importation and libration of parasites in New England many shipments of parasites have been sent from the New England area to other parts of the country and even to foreign countries. Pine tip moth parasites and Compsilura concinnata will be discussed later. Satin moth parasites[3] of European orogin collected in New England and established in Washington have proved valuable control agents. Many gypsy, brown-tail and satin moth parasites collected in New England have been sent to Canada. Ooencyrtus kuvanae, a gypsy moth egg parasite, originally from Japan, was established in Spain from shipments made from New England. Control of the golden oak scale in New Zealand is largely attributed to shipments of the parasite Habrolepis dalmani made from the vicinity of Boston, Mass. A valuable indigenous parasite of elm leaf beetle pupae originally reared in Massachusetts has been established in California.

Important contributions to the knowledge of parasites have been made in numerous publications by several authors. These papers have dealt largely with the biology, habits, and host relationships of parasites, and their propagation and dissemination.

Special investigations have also been made regarding diseases of the gypsy and brown-tail moth that are important contributions to this phase of biological control.[4]

(see p.38a for references)

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Table 1. Summary of Colonization and Establishment of Parasites & Predators

Host	Area of Colonization	Number of Species Liberated	Established	Commonly Reared [1]	Remarks on Parasites
Gypsy Moth Porthetria dispar	New England	37	11	6	European and Oriental species
Brown-tail moth Nygmia phaeorr-hoea	New England	15	8	7	European species
Satin Moth *Stilpnotia sa-licis*	New England	13	6	3	One native species from Washington liberated in New England. Other specie s European
	Washington and Oregon	10	4	4	European species
Elm Leaf beetle *Galerucella luteola*	New England-New Jersey	2	0		European species
	California	2	1		The species established in California is native to New England. The other species liberated is European
Oriental Hag Moth *Cnidocampa flavescens*	New England	1	1	1	Oriental species

1. Species "commonly reared" may be considered as exerting some meaaure of control from time to time.

Continued on 39 a

Table 1. Summary of Colonization and Establishment of Parasites and Predators

Host	Area of Colonization	Liberated	Number of Species		Remarks on Parasites
			Established	Commonly Reared[1]	
Larch Case Bearer *Coleophora laricella*	New England New York	5	2	2	European species
	Michigan	1	1		European species
European pine shoot moth *Rhyacionia buoliana*	New England New York New Jersey	16	3	3	European species
Birch leaf-mining sawfly *Phyllotoma nemorata*	New England New York	5	2	2	European species
European spruce sawfly *Diprion polytomum*	New England New York	14	1	1	One European species received from Canada. *Microplectron fuscipennis*, liberated in large numbers and generally established. Eleven European species received in very small numbers from Canada. Two native species received from Oregon

1. Species "commonly reared" may be considered as exerting some measure of control from time to time

Continued on page 39 b

Table 1. Summary of Colonization and Establishment of Parasites and Predators

Host	Area of Colonization	Number of Species[1]			Remarks on Parasites
		Liberated	Established	Commonly Reared	
European earwig *Forficula auricularia*	New England	1	1		European species received from Oregon
Fir bark louse *Adelges piceae*	New England	1			European species received from Canada
Forest Tent Caterpillar *Malacosoma disstria*	Minnesota	2			European species received from New England
Fir tussock moth *Hemerocampa pseudotsugata*	Idaho	2			European species sent from New England
A Sawfly *Neodiprion sertifer*	New Jersey	1			Native species sent from Oregon
Pine tip moth *Rhyacionia frustrana bushnelli*	Nebraska	8	4	1	Native species: 7 from Virginia, 1 from Mass.

1. Species "commonly reared" may be considered as exerting some measure of control from time to time.

Studies show that in certain areas in New England the aggregate effectiveness of imported parasites of the gypsy moth approaches that obtained in central Europe. This is an indication that the objectives of the importation work are being realized.

One of the most striking examples of control of a forest or shade tree insect by an imported parasite occurred in the case of the Oriental hag moth which was a serious defoliator of several species of shade trees, principally maples in the environs of Boston, Mass. a few years ago. This moth was accidentally introduced from the Orient and to combat it a tachinid parasite (Chaetexorista javana) was imported. Within three years the hag moth was completely controlled and no defoliation of consequence has occurred since. An outstanding example of control by native parasites transferred from one region of the country to another was the introduction in 1925 of parasites of the pine tip moth from Virginia to Nebraska, for the control of a variety of this moth, which was causing serious damage to pine plantations in the Nebraska National Forest. Within 5 years one of the introduced parasites, Campoplex frustranae Cush., was destroying between 80 and 90% of the host over much of the area. The young trees, many of which had been stunted for years by repeated destruction of the new leaders, made a rapid recovery and in some plantations the trees added more height growth in the three years following release from injury than in the previous 10 to 15 years. Unfortunately about this time a second species

of tip moth began causing heavy damage in this isolated plantation area. It was found that the introduced parasite could not develop in this second species, and consequently failed to bring it under control. Conditions are about as bad now as before since this second species, without adequate parasites has become as serious as the original species of tip moth. Such excellent control of forest or shade tree insects through parasites is, however, very exceptional. In most cases parasites must be considered as only contributing factors in the natural control of an insect and experience has shown that usually several years must elapse before effective parasitism is obtained over areas of considerable extent.

Some imported parasites of polyphagus habits may be utilized to advantage in combatting other forest insects closely allied to the host for which the parasite was originally introduced. Compsilura concinnata, a tachinid parasite originally introduced into New England as a gypsy moth parasite has been found to attack over 125 species of native lepidopterous larvae. The Division of Forest Insect Investigations has already made several shipments of this parasite to other sections of the country where outbreaks of lepidopterous defoliators occurred. It is planned to extend this work until this parasite is established in all major forest regions of the U. S. There are other parasites, both native and introduced, which offer possibilities along these lines.

An exhaustive study of the parasites of Lepidoptera[1] and sawflies occurring in the northeast has been made. These studies are now being extended to other sections of the country.

One phase of the biological control problem which is receiving increased attention in the Division of Forest Insect Investigations is a study of the effectiveness of insect enemies in relationship to the effectiveness of other factors of natural control such as climate, topography, stand composition, etc. Encouraging results are being obtained along these ecological lines of investigation with the gypsy moth in New England, the forest tent caterpillar in the Lake States, and bark beetles in the west.

Struble (1930)[2] has made studies of insects associated with bark beetles in pine in California, and at the present time is experimenting with the possible use of beetle predators in bark beetle control. Rust (1932, 1933, 1935)[3] and

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1. Schaffner, J.V.Jr. and C. L. Griswold
 Macrolepidoptera and their parasites reared from field collections in the northeastern part of the U. S. - Misc.Pub. 188 USDA 1934 155 pp.
2. Struble, G. R.
 The biology of certain Coleoptera associated with bark beetles in western yellow pine. - Univ. Calif. Ent. Publications 5 (6): 105-134
3. Rust, H.J.
 Ants and rodents aid in the control of mountain pine beetle - Forest Worker July 1932

 Many bark beetles destroyed by predaceous mite - Jour. Econ. Ent., 26 (3): 733-4 - 1933

 The role of predatory agents in the artificial control of the mountain pine beetle - Jour. Econ. Ent. 28 (4) 688-691 - 1935

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De Leon[1] (1935) studied the parasites, predators and other insects associated with the mountain pine beetle in Idaho and Montana. Bedard[2] has recently recorded the insects associated with the Douglas fir beetle in Idaho, and similar studies are now under way with the Black Hills beetle at the Fort Collins, Colorado, laboratory. One of the objects of this work on bark beetle predators and parasites has been to develop some means of recognizing beetle infested trees in which these natural enemies are especially abundant. During artificial control operations such trees would then be left untreated so as to favor the increase of the predators and parasites.

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1. De Leon, Donald - 1935 - A Study of Medetera aldrichii Wh., a predator of the mountain pine beetle (Dendroctonus monticolae Hopk.) - Entomologica Americana 15 (2):59-90

   1935 - The biology of Coeloides dendroctoni Cush., an important parasite of the mountain pine beetle (Dendroctonus monticolae Hopk.) Ann. Ent. Soc. Amer. 28 (4):411-424

2. Bedard, W. D. - 1938 - An annotated list of the insect fauna of Douglas fir in the Rocky Mountain Region. Can. Ent. 70:188-197

Insecticides and their application in Forest Entomology:

The control of forest insects is far more a matter of prevention through adjustment of lumbering or forestry practices than control through the application of insecticides. However, insecticides do have their use in preventing destruction of valuable stands of timber by defoliation, for the control of shade tree insects, and to an increasing extent for the control of insects attacking forest products.

Some of the earliest work with insecticides in the Division was for the control of the locust borer. Hopkins[1] (1907) recommended a kerosene emulsion and later Craighead[2] (1919) suggested the addition of an arsenical to the emulsion to take advantage of the habit of many of the larvae in coming to the surface and feeding on the bark. St. George and Beal[3] (1932) made use of a fumigant spray for this same insect. The use of such sprays has been widely adopted against other boring insects.

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1. Hopkins, A. D. - 1907. Some insects injurious to forests: additional data on locust borer. USDA Bur. Ent. Bul. 58. Part 3.

2. Craighead, F. C. 1919 - Protection from the locust borer. USDA Bul. 787

3. St. George, R. A. and Beal, J. A. - 1932 - New sprays effective in the control of the locust borer. Jr. Econ. Ent. 25: 713-721

Orthodichlorobenzene is now very widely used as an insecticide and fumigant spray against borers in logs and forest products and for control of termites. Our first experimental work with this material was about 1919 at the East Falls Church, Va. laboratory by St. George, Craighead, and Snyder. It is not clear at this time whether the use of this material originated within the Division or whether it was suggested from some other source. The earliest reference to our work appears in the report of the Chief of the Bureau[1] (1923).

Since the earliest days of the Division, there has been a demand for sprays to be applied to logs or lumber to prevent the attack of ambrosia beetles, bark beetles, borers, and powder-post beetles. Systematic tests with different chemicals were conducted for several years by Craighead and St. George[2] (1922) at East Falls Church, Va. Although no spray was found which was effective against ambrosia beetles, which live on a fungus in the wood rather than on the wood itself, the other wood feeding types were prevented from attacking green logs by the use of a mixture of coal-tar creosote and kerosene. Pyridine is another chemical which proved to be an effective repellent but its objectionable odor precludes its being used extensively.

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1. Howard, L. O. - 1923. Report of the Entomologist, USDA for 1921-1922

2. Craighead, F. C. - 1922. Experiments with spray solutions for preventing insect injury to green logs. USDA Bul. 1079.

In another series of tests conducted at Asheville, N. C. during 1929 by St. George[1], it was determined that orthodichlorobenzene was effective in killing borers and bark beetles in green logs. This discovery is of importance in connection with the control of insects infesting woods used in rustic construction where retention of the bark is often desired for esthetic reasons. Subsequent tests conducted during 1932 revealed that a pine oil mixture known as "Cabinol" and "Reilly's Penetrating Transparent Creosote" are also effective for the same purpose.

Since 1935 Snyder, at the New Orleans, La. laboratory, with the cooperation of several lumber companies has been carrying on more extensive experiments with chemical dips and sprays against ambrosia beetles attacking logs and lumber. Up to the present time no spray has proven effective against ambrosia beetles. This agrees with past experience and indicates that ambrosia beetles can most easily be controlled by prompt utilization and rapid seasoning, as advocated by Hopkins (1910)[2]. End racking lumber for 10 to 14 days before piling causes sufficient drying to prevent ambrosia beetle attack.

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1. St. George, R. A. - 1929 - Protection of log cabins, rustic work and unseasoned wood from injurious insects. USDA Farmers' Bull. No. 1582

2. Hopkins, A. D. -1910 - Insect Injuries to Forest Products - Bur. of Ent. Circular No. 128

While the use of fish oil did not originate in the Bureau, it is believed that the following publications represent the first demonstration of the application of sprays containing such oil as a sticker on forest or shade tree insects. A tree banding material was also developed to take the place of the expensive "tanglefoot".

1920 - Collins, C. W., and Hood, C. E., Gypsy moth tree banding material. How to make, use and apply it. USDA Bul. 899, 18 pp. illus.

1926 - Hood, C. E. Fish oil, an efficient adhesive in arsenate of lead sprays. USDA Bul. 1439

1929 - Hood, C. E. Fish oil as an adhesive in lead arsenate sprays. USDA Tech. Bul. III

Termite Control: The study of termites and termite control is one of the older projects of the Bureau. Dr. Howard and Dr. Marlatt jointly published a bulletin[1] in which sound principles in termite prevention were advocated, namely structural alterations to break the contact of wood with the ground. This is still the basis of all present recommendations. In fact, subsequent progress has been more along the lines of testing different chemicals to be used as wood preservatives and, in recent years, as soil poisons. The metal termite shield has been in use for a great many years in the Tropics and it is not known when first reference to its use was published. Snyder[2] (1926) first makes mention of it as a Bureau recommendation.

For a number of years cooperative tests have been conducted with the Forest Products Laboratory and the Office of Forest Pathology on wood preservatives to determine those effective in preventing termite attack. These tests were begun in 1912 at East Falls Church, Virginia, and in the Canal Zone in Panama in 1928. Similar tests have been under way for many years in several places in the United States and in some foreign countries

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1. Howard, L. O. and Marlatt, C. L. - The principal household insects of the U. S. - Bull. No. 4, New Series USDA pp. 70-76. 1896.

2. Snyder, T. E. - Preventing damage by termites or white ants. USDA Farmers' Bulletin No. 1472, 1926.

through the assistance of cooperators. Coal-tar creosote stands out as the most effective wood preservative known today, where wood is placed in contact with the ground, and zinc chloride, where wood is to be used inside buildings as partititions, wall boards, furniture, etc., where it is dry. Dr. Howard and Dr. Marlatt in 1896 also recommended coal-tar creosote impregnated wood, where supports had to contact the ground, so as to protect them from attack by termites and decay. As the result of the Virginia tests, Snyder in 1915 indicated that such preservatives as chlorinated naphthalene, zinc chloride and mercury chloride would probably protect wood from termite attack where it is not used in contact with the ground. These chemicals have remained effective under severe tests up to the present time. In 1916 Snyder[1] reported on chemicals effective in protecting wood pulp and wall board from termite attack by the use of dihydrogen potassium arsenate, mercury bichloride, zinc chloride and copper sulphate. These chemicals are introduced into the products during the manufacturing process. In 1924 crude carbolic acid, coal-tar creosote and sodium fluoride were mentioned in the same capacity. The results of several years tests with other wood preservatives indicate that chlorinated naphthalene, chromated zinc chloride,

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1. Snyder, T. E. - Termites or white ants in the U. S; their damage and methods of prevention. USDA Bull. #3. 1916

zinc-meta-arsenite and such proprietary substances as Aczol (copper-zinc-phenol mixture). Tenalith-U (fluoride in phenol mixture), and Celcuresol (mixture of copper sulphate, potassium dichromate and pyroligneous acid), also have considerable merit. Dr. Marlatt[1] in 1908 reported the use of California redwood in Manila to keep termites out of cabinets containing valuable records. In 1915 Dr. Snyder reported on several native and exotic woods he had tested and which resisted termite attack.

The extensive use of soil poisons against termites was, as far as we know, first developed by private concerns. However, it is interesting to note that Dr. Howard and Dr. Marlatt recommended drenching the soil beneath buildings with kerosene as early as 1896. Hydrocyanic acid was suggested by Dr. Marlatt[2] as a fumigant to be used for the control of subterranean termites in buildings as early as 1902 in instances where entire buildings needed treatment. Later the use of this fumigant for the control of subterranean termites was discontinued. This Bureau did not emphasize soil poisoning treatments for several years. First published mention

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1. Marlatt, C. L. - The White Ant - Bur. of Ent. Circ. No. 50, second edition revised. 1908.
2. Marlatt, C. L. - The White Ant - Bur. of Ent. Circ. No. 50, second edition

was made in 1931 in a mimeographed letter[1]. For the past five years extensive tests of soil poisons have been carried on in cooperation with the R. C. A. Communications at Riverhead, Long Island where 680 cedar poles have been treated with 70 chemical preparations. In addition to this some 200 houses have been treated through cooperation with the owners in three different localities in eastern United States. We are fully satisfied with the effectiveness of several soil poisons for a period of at least five years. Such materials as coal-tar creosote diluted with petroleum oils, various arsenicals, chlorinated naphthalene, orthodichlorobenzene and at least two proprietary mixtures are quite satisfactory.

Although the Bureau of Entomology and Plant Quarantine has undoubtedly been a leader in this country in advocating sound methods for termite control its energies, aside from testing the value of various preservatives and poisons have been devoted primarily to service work to acquaint the public with the true status of the problem and to get builders and architects and officials in charge of building codes in the various communities to adopt the Bureau's recommendations

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1. Snyder, T. E. Supplement to Depart. Agric. Leaflet No. 31 Termites in Buildings, June 1929 pp. 1-5 Supplement entitled "For the control of subterranean termites - soil treatment" 1931.

to protect new as well as old buildings from termite attack. The desirability of obtaining community action to revise building codes was first mentioned by Dr. Snyder[1]. Aside from this and taxonomic and biological work on termites,[2, 3] the development of new and effective ideas in control has not been outstanding.

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1. Snyder, T. E. Preventing damage by termites or white ants - USDA Farmers' Bulletin 1472, 1926.

2. Banks, N. and Snyder, T. E. - Revision of the Nearctic Termites - Bull. 108, U S National Museum, April 13, 1920.

3. Snyder, T. E. - Our Enemy - the termite - Comstock Pub. Co., Ithaca, N. Y. 196 pp. 56 figs., 9 pls. 1935.

Application of Insecticides from the Air: - One of the first successful attempts to control forest insects by applying insecticides from airplanes was conducted by Houser in 1921[1] at the Ohio Agricultural Experiment Station. Later, Fracker and Granovsky (1927)[2] demonstrated the feasibility of controlling the hemlock looper with airplane dusting. In 1926 and 1927[3] approximately 350 acres of gypsy moth infested woodland in eastern Massachusetts were treated by applying oil-coated and uncoated arsenical dusts from an airplane. Even under ideal flying conditions it was difficult to control the dust cloud. A low insecticidal deposit and poor adherence was obtained and consequently little control resulted on nearly one half of the area treated.

In the summer of 1931 a rather extensive airplane dusting project to control an outbreak of the hemlock looper was conducted under the direction of F. P. Keen[4] by state and private timber owners in Washington. Some $15,000 was expended. While fairly satisfactory control was obtained, the results were spotty in character and demonstrated that the fast-moving modern airplane cannot be depended upon to apply dusts over rough, forested terrain in a uniform and reliable manner.

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1. Houser, J. S. (1923) - Dusting tall trees by airplanes for leaf eating insects. - Jour. Econ. Ent., Vol. XVI, pp.241-249
2. Fracker, S. B. and Granovsky, A. A. (1927) - The control of the hemlock spanworm, Ellopia fiscellaria, by airplane dusting. Jour. Econ. Ent. Vol. XX, pp. 287-295.
3. Barnes, D. F. and Potts, S. F. (1927) - Airplane dusting experiment for gypsy moth control - Jour. Econ. Ent., Vo. 20, No. 1.
4. Keen, F. P. (1932) - The control of hemlock loopers by airplane dusting - Jour. of Forestry, 30 (4): 506-507.

From this time on the Division has been searching for better methods of application of insecticides over forested areas and several tests have been made with the autogiro. One of the first practical trials with an autogiro by this Bureau was that made under the technical direction of Collins, Potts and Whitten, in cooperation with the National Park Service, in an attempt to control an outbreak of canker worms in Morristown National Historic Park. The insecticide was applied under contract by Giro Associates and the results were published by E. H. Francis of the National Park Service in the Proceedings of the 12th Shade Tree Conference, 1936. This work demonstrated the far greater practicability of the giro over the airplane for forest conditions. Several other extensive tests have been made in connection with attempts to develop better apparatu for releasing sprays or dusts from an autogiro and in 1938 about 200 acres of woodland were sprayed for control of the gypsy moth.[1]

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1. Potts, S. F. (1939) - Spraying woodlands with an autogiro for control of the gypsy moth - Journ. of Econ. Ent. Vol. 32, No. 3, pp. 381-387

The autogiro has the advantage of being capable of slow flight, taking off and landing in smaller fields, greater maneuverability and is safer than the fast moving airplane. It has, however, the disadvantage of being unable to carry as heavy a load as the airplane. The concentrated spray when released as a fine mist produced a heavier deposit on the foliage, drifted less and adhered better than dust. By the application of this method very good results have been obtained in controlling the gypsy moth and canker worms. It is believed that where spraying of large areas of parks or woodlands is feasible this method offers considerable promise.

Concentrated Spray Mixtures: Recent advances have been made by the Division of Forest Insect Investigations in the development of spray mixtures of high concentrations for practically all of the more important insecticides and fungicides. These mixtures are from 25 to 500 times more concentrated than standard sprays. Tests with these concentrated sprays indicate that they possess many advantages over ordinary sprays or dusts. Adherence to foliage is increased and loss due to run-off is entirely removed. Deterioration of organic residues is reduced. Foliage injury is less. It is believed that the use of these concentrated sprays will reduce the cost of spraying and increase the rate of speed of application, although satisfactory equipment has not yet been developed for applying them from the ground. Experiments have shown that such

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[illegible]

insects as the white pine weevil and European pine shoot moth may be satisfactorily controlled by these sprays while sprays of the usual concentration are ineffective.[1, 2]

<u>Adhesives and Carriers for Insecticidal Dusts</u>: - Most of the important insecticides have been tested with and without adhesives and carriers. Several new carriers were developed among which barite, a fine, heavy material, was particularly effective in reducing drift. Experiments showed that the effectiveness, adherence, and deposit of dusts could be greatly increased by using certain materials, as glycerine for example, for absorbing moisture from the air. Adherence was increased by the addition of semi-drying oils, dehydrated molasses and milk solids.[3, 4]

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1. Potts, S. F. - Concentrated Spray Mixtures for Aerial Spraying. - Jour. of Econ. Ent. August 1939, Vol. 32 #4 Pages 576-580
2. Potts, S. F. and Whitten, R. R. - Further tests with concentrated spray mixtures for aerial spraying - (in manuscript)
3. Barnes, D. F. and Potts, S. F. - Adherence of some insecticidal dusts to growing and mature foliage - Jour. Econ. Ent., Vol. 22, No. 6.
4. Potts, S. F. and Barnes, D. F. - Adhesives and carriers for insecticidal dusts - Jour. Econ. Ent. Vol. 24, No. 5, p. 1110

Studies of Residues from Sprays of Standard Concentration:

Studies have been made of the insecticide deposit per unit of leaf area, the adherence of the insecticide and the deterioration of organic and inorganic insecticides on different plant species. It was found that most insecticides applied without stickers adhered poorly. Most spreaders now in use reduced the deposit by nearly 50 percent. In ordinary woodland spraying only 40 to 60 percent of the spray applied is actually deposited on the tree foliage. Eighty-five to 90 percent as much deposit is obtained on wet foliage as on dry foliage.

Foliage Injury Investigations: Buffered leaf acids from the plant and carbon dioxide from the air were found to be the primary causes for the breaking down of arsenicals and Bordeaux mixture on the plant. The rate of absorption of free arsenic and copper was determined as well as the difference in tolerance of several species of plants grown in different environments. Special methods for making these studies were devised. Histological studies were made of affected leaf tissues. Bordeaux mixture (3-5-100) greatly reduced the solubility of all arsenicals on the plant and increased their adherence. Ferrous sulphate ($FeSO_4 \cdot 7H_2O$) plus hydrated lime (4-1) considerably increased the adherence and reduced the injury by lead arsenate, making possible a reduction in concentration and number of applications. The investigations

indicated that certain metallic sulphates and hydroxides such as ferrous sulphate, zinc sulphate, and copper sulphate, could be added with a small amount of hydrated lime to arsenic compounds to produce much safer insecticides.

Concentrated spray mixtures greatly reduced the amount of injury by various insecticides over that by ordinary spray concentrations, since it was possible to coat the residue with protective agents. Of special value also was the discovery that diluted and undiluted corn, cottonseed, and soybean oils can be safely used as insecticides on all the plants tested.

1. Potts, S. F. - A factor concerned in arsenical injury to foliage - Jour. Econ. Ent. Vol. 23, No. 2.
2. Potts, S. F. - Foliage injury caused by arsenicals and Bordeaux mixture - (In manuscript)

Toxicological and Physiological Investigations: The most complete toxicological studies were conducted on the gypsy moth. Laboratory and field methods of study were devised. Toxicity was determined in relation to time, instar, dosage, and weather. The median and minimum lethal dosages were found. The weight and area of leaves consumed were determined in relation to instar, weight of larva, time of treatment, and dosage. The toxicity of various insecticidal agents were measured. The moisture and solid content of the larvae and food was determined.

A determination was made of the pH in the food and digestive tract; the enzymes and the anions and cations in the digestive tract; the solubility of arsenicals in the gut; the quantities of arsenic found in different kinds of tissue; the proportion of arsenic found in the body and in the frass; and the effect of insecticides on the digestive tract as determined by histological sections.

Toxicity tests were made on 12 species of Lepidoptera, 3 Coleoptera, 5 Homoptera and 5 Hymenoptera (sawflies) and the proper dosage for use under field conditions was determined for each species.

Some fungicides were found to be toxic as stomach poisons to certain insects. For example complete kill of all 5 species of sawflies studied was obtained from an application of 3 percent lime sulphur or 12 pounds of sulphur per 100 gallons of water. These two compounds were also effective as stomach poisons against the eastern tent and forest tent caterpillars.

Potts, S. F., Whitten, R. R., Hood, C. E. and Symonds, C. M. Insecticidal and physiological investigations for effecting better gypsy moth control at lower costs - (in manuscript)

Collins, C. W. and Potts, S. F. - Attractants for the male gypsy moth - Jour. Econ. Ent., Vol. 24 (2):561

Collins, C. W. and Potts, S. F. - Attractants for the flying gypsy moths as an aid in locating new infestations - Tech. Bull. No. 336, 1932, 44pages illus.

A quantitative field method for measuring the degree of control by different insecticides was developed in which the weight of frass falling on cloth-bottomed, wooden-framed trays was measured in treated and untreated areas.

The composition and weight of foliage per unit of area was found to vary considerably for different tree species and at different crown canopy levels.[1]

A method for trapping male gypsy moths was developed. This involves the preparation of an extract from certain glands of the female and exposing the extract in specially designed traps in the field. This method provides a relatively inexpensive means for detecting the presence of gypsy moths in lightly infested areas.

The use of a 2% white oil emulsion for dipping pine nursery stock to prevent the spread of the pine tip moth in the egg stage was developed about 1927 by Baumhofer[2] at Halsey, Nebraska, on the Nebraska National Forest. This has been widely used since then through the dissemination of mimeographed instructions but nothing has been published.

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1. Potts, S. F. - Weight of Foliage from Different Crown Levels of Trees - Jour. Econ. Ent., Vol. 31 (5):631
2. Baumhofer, L. G. - Preventing the distribution of pine tip moths on nursery stock - Brief E-366, January, 1936.